A Bioluminescence Bathyphotometer for an Autonomous Underwater Vehicle

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LONG-TERM GOAL

Biological oceanographers have been limited to describing oceanic events based on data sets that are spatially or temporally restricted, or both. With the aid of new autonomous underwater vehicles (AUVs), such as the REMUS (Remote Environmental Monitoring UnitS), one can now sample marine environments more rigorously, more frequently, and with less restriction from inclement weather than has been previously possible until the advent of this new technology. Our long-term goal is to exploit this new technology to improve understanding of the dynamics of fine-scale bioluminescent plankton distribution.

OBJECTIVES

We proposed to build two new type bathyphotometers. The first, designed for deployment on the spatially confined REMUS platform, would still retain the desirable properties of, and excitational and photometric calibration traceability to, our larger systems in current use (Hidex, Towdex, Moordex). A second unit of the same design would be designed for operation independently of REMUS so as to serve as a test platform during the development of the REMUS unit and ultimately to be used for general bioluminescence profiling and towing during comparisons with the REMUS unit and in general research.

APPROACH

The two bathyphotometers were designed to meet the integration specification provided by the WHOI REMUS Development Group headed by Chris Von Alt. In these bioluminescence detectors mechanically stimulated bioluminescence was generated in a 500 ml detection chamber by a helical impeller and detected with a Hammamatsu H5783 photomultiplier. Flow rates were measured and regulated via a Hall effect flowmeter. A reflectance turbidity meter, to provide data for a protocol developed by Dr. David Lapota (Space and Naval Warfare Systems Center) was installed. A chlorophyll fluorometer was provided to assist in identification of luminescence phytoplankton sources.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE **A Bioluminescence Bathyphotometer for an Autonomous Underwater Vehicle**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of California at Santa Barbara,Department of Ecology, Evolution, and Marine Biology,Santa Barbara,CA,93106**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

The REMUS independent unit has been extensively used in studies in Puget Sound and the Santa Barbara Channel (See Alldredge, Case and MacIntyre in this volume). It has also been run against the bioluminescence detector system used by Lapota to obtain a transfer function to his visibility protocol. The REMUS unit was successfully integrated and operated off Woods Hole in April 1999.

At the LEO-15 study site in late July 1999, the system on a REMUS (Figure 1), was tested for the first time at night. Two 1-hour consecutive runs were performed by the REMUS through the dusk to darkness transition. Bioluminescent intensity, fluorescence, backscatter intensity, and water flow through the bathyphotometer were recorded and analyzed over the sampling grid (150-m by 300-m rectangle).

Another bathyphometer, identical to the one on the REMUS, was profiled during the same time period on the O. Scofield optical instrument cage. This study covered a larger sampling area than the REMUS runs (approximately 1-km by 1-km square) in order to produce a high-resolution map of the distribution of bioluminescence in this coastal ocean system. Ancillary data from the nearby LEO-15 nodes were also added to the data collection.

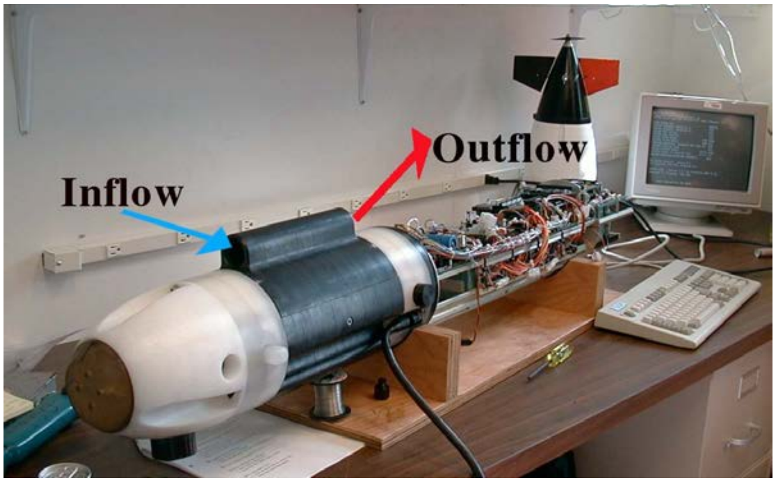

Figure 1: Bathyphotometer integrated with a REMUS AUV. Arrows indicate intakeand exhaust ports of the instrument.

WORK COMPLETED

The REMUS AUV test and sampling plan were a success at the LEO-15 study site on July 22, 1999. Collaborations with Oscar Scofield (Rutgers Univ.) and Mark Moline (California Polytechical State Univ.) are underway to analyze this data. We have begun preparations to place another REMUS-type bathyphotometer on a profiling optical mooring at LEO-15 in June 2000.

RESULTS

Three-dimensional high resolution maps of bioluminescence, fluorescence, and backscatter at the LEO-15 site were constructed using data collected when the REMUS

with the bathyphotometer sampled in an undulating pattern from 3 to 6 m.(Figure 2A and 2C). We are currently collaborating with Mark Moline (Cal Poly) to determine a sampling pattern that would most accurately and efficiently sample the whole flight area in future operations.

We conclude from this preliminary data that over a relatively small area (150 m by 300 m) there were two distinct types of bioluminescent communities, (1) autotrophic and heterotrophic plankton distributed within phytoplankton peaks, and (2) heterotrophic plankton not associated with phytoplankton peaks. Figure 2B and 2D show bioluminescence in three dimensions. The data was collected approximately one hour apart. Structural change, from flat “laminar” layers in Figure 2B to more numerous smaller patches in Figure 2D, is apparent, which alludes to the dynamic nature of coastal systems influenced by strong wind and tidal forces.

Bioluminescence and fluorescence appear to correlate in some sections of the maps, but are spatially distinct signals in adjacent areas as shown in Figure 3. We plan to repeat this study with the REMUS next summer for further testing and calibration of the bathyphotometer.

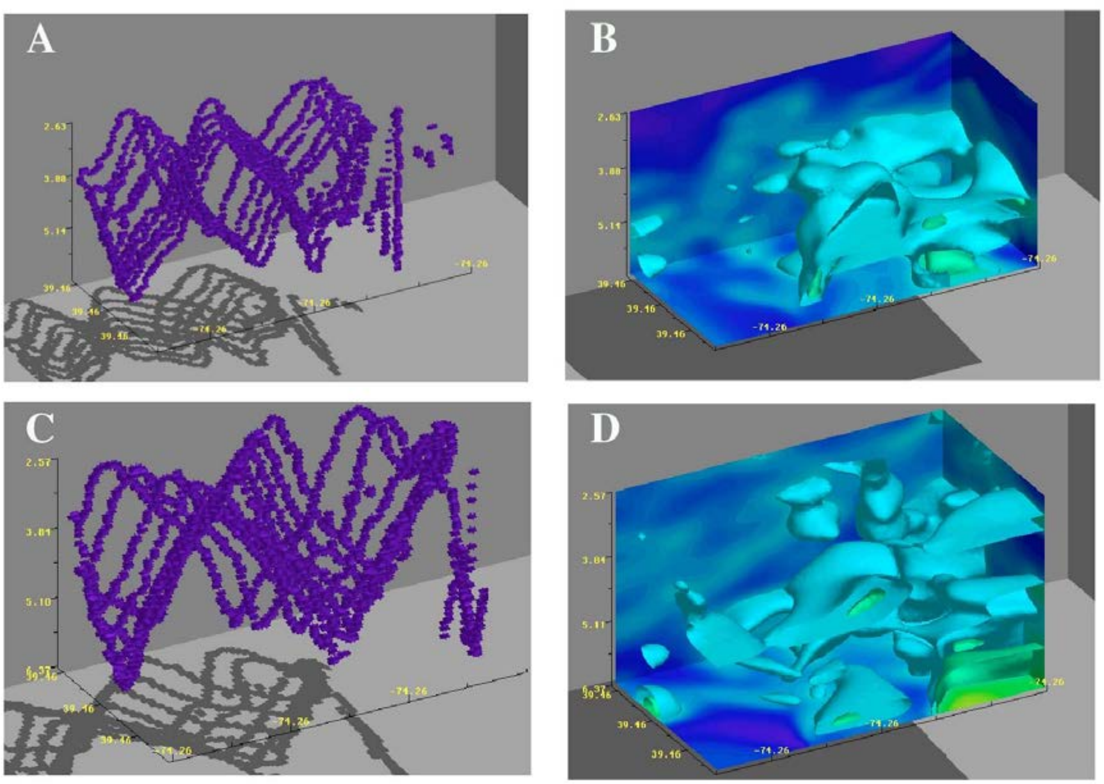

Figure 2: REMUS flight paths on July 22, 1999 and bioluminescence (BL) intensities (photons/ sec/ 350 ml).The x, y, and z-axes show longitude,latitidue, and depth (m) respectively. The REMUS was programmed to undulate from 3 to 6 m over the sampling area. A) Flight 1 occurred at 20:00(dusk). B) BL during flight 1 C) Flight 2 occurred at 21:00 (darkness)D) BL during flight 2

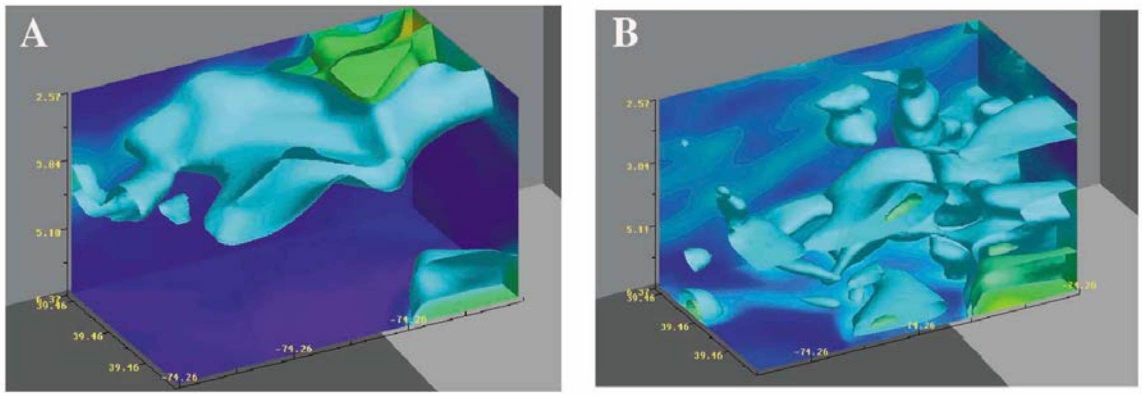

Figure 3: (A) Fluorescence and (B) bioluminescence intensities (photons/ sec/ 350 ml) from REMUS flight 2.The x, y, and z-axes show longitude,latitidue, and depth (m) respectively.Maps are color-coded, green(1.1x 10^{11}) represens contours with higher intensities than blue(5x 10^{10}).

IMPACT/APPLICATION

The new bathyphotometer system has successfully been developed for several sampling modes, and has been deployed in three different marine environments, specifically to perform high-resolution sampling in coastal waters. This has made it possible to test for thin layers, to be integrated with the REMUS AUV, and to be placed on profiling cages with other instruments that might have been disturbed by past bathyphotometers.with high intake rates (6 l/ sec HIDEX versus 350 ml/ sec for the new units). We believe this work represents the first measurements of bioluminescence from an AUV.

TRANSITIONS

Plans are underway to provide a second REMUS with a bathyphotometer system (Moline and J. Case) for use in studies along the southern Californian coast in order to take advantage of the very well studied bioluminescent plankton communities in the Santa Barbara Channel and off San Clemente Island.

An identical bathyphotometer will be built in 2000, and placed on the LEO-15 optical node for high-resolution temporal sampling during June and July 2000, and we hope indefinitely, in order to document bioluminescent population reactions to upwelling events and throughout the year.

RELATED PROJECTS

1 – D. Van Holiday (Marconi North America, formerly Tracor) – We are examining correlations between zooplankton distributions measured acoustically by Holiday and distributions of bioluminescence, phyto- and zooplankton, and marine snow. Christy Herren was trained on the TAPS-6 operation to use in two field studies in the Santa Barbara Channel this year in conjunction with bioluminescence measurements.

2 - Mark Moline and Oscar Scofield (California Polytechnic State Univ. and Rutgers Univ.) –During the REMUS flights in July 1999 at the LEO-15 site, we collaborated with Oscar Scofield and Mark Moline to obtain preliminary bioluminescence data with concommitant optical data. This will be used to plan data collection from the new optical mooring with a bathphotometer that will take place June 2000.

3 – David Lapota (Space and Naval Warfare Systems Center, San Diego) – A proposed use of the system will be in collecting data on visibility effects of coastal bioluminescence, for which an algorthym has been developed by David Lapota. This work will continue in the Southern California Bight where the most detailed annual studies of bioluminescence have been made (see references).

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